INTERNATIONAL UNION OF RADIO SCIENCE
SOVIET NATIONAL COMMITTEE

REPORT

to XVII General Assembly of URSI
1969—1971

K. I. Gringauz

Ionosphere
Commission III

1972

U R S I

SOVIET NATIONAL COMMITTEE

Commision III-Ionosphere

K.I.Gringauz

REPORT TO XVII GENERAL ASSEMBLY OF URSI FOR 1969-1972

Contents

1. Structure and physics of F-region during quiet conditions 2
2. Vertical profiles of ionospheric parameters and ion composition 3
3. Physics of lower ionosphere 6
4. The disturbed ionosphere 7
5. Sporadic E_s-layer 9
6. Inhomogeneities and motions 10
7. Radiowave propagation in ionosphere 12
8. Electric field in Earth's ionosphere and magnetosphere and its influence on ionospheric dynamics 13
9. Other points 14
10. References 15

Warsaw, 1972

I. Structure and physics of F-region during quiet conditions

On the basis of new results of rocket and satellite observations in the frame of the nonstationary model of the ionospheric F-region it is shown that ionization, recombination and transport due to the ambipolar diffusion are fundamental processes forming the ionospheric F-region at middle latitudes under complicated conditions. It is also shown that although the diffusive transport is one of principal causes of the forming of F_2-region maximum, the diffusion at the maximum may be neglected and some parameters discribing rate of the chemical reactions and of the ionization may be obtained from daily variations of the electron density (Klimov et al.1969; Velichansky et al.1970; Klimov, Solovijev,1968; Velichansky et al. 1971; Nikanorova, Schukina, 1970; Schukina,1970).

The detailed analysis of the F-region morphology was carried out on a world scale (season, latitude, longitude variations of F_2 during the high and low solar activity phases). It is shown that season variations main features of F_2 may be explained as the result of the combined effect of a diffusion flux and solar short wave radiation acting in antiphase (Besprozvannaya, 1970 a,b).

The development of the season anomaly in the space (in latitude and altitude) and the time in the lower F_2-region and in the outer ionosphere was studied with use of the data of the ground vertical sounding and of the sounding from the "Allouet-1" satellite.

1) It is shown that the season anomaly is the phenomenon clearly localized in latitude, altitude ($180\text{-}200 \leq h \leq 500$ km) and time (8^h30^m - 18^hLT) and in outer ionosphere and lower F_2-region the height of the anomaly depends on time; in the morning and evening it is observed only at heights $h=h_{max}$ of F_2-layer and the maximum altitude of the anomaly is observed in the afternoon ($14\text{-}15^h$LT) in outer ionosphere at middle latitudes.

2) The season anomaly is observed in the upper atmosphere only at the latitudes and heights where ions O^+ dominate in the ion composition.

The quantitative interpretation of peculiarities of the latitudinal, altitudinal and temporal development of the season anomaly may be only obtained with taking into account of season variations of thermosphere and neutral composition at turbopause levels: in summer n(O) is approximately by 50% less than in winter and at turbopause levels $n(O_2)$ or $n(N_2)$ increase approximately by factor of two from winter to summer (Fatkullin,1970a,b, 1971; Boenkova,1970).

The theory of the F_1-region and the F_1-layer development is proposed in which the criterion of the F-region splitting into F_1-layer and F_2-layer is established. It is shown that the more is the rate of ion-molecular reactions the less is the time for the forming of the F_1-layer. H(h)-profile of F_1 and F_2-layers during quiet periods is formed of the value of the rate-coefficient of the ion-molecular reaction rate is $5 \div 8 \cdot 10^{-13} cm^{-3} sec^{-1}$. Such a value is less than well known laboratory estimations by factor of $2 \div 4$ (Koshelev, Schepkin, Shuiyskaya, 1970a,b; Koshelev, Schepkin, Toporkov,1970; Koshelev, Schepkin,1970; Klimov, Schepkin,1970; Schepkin,1968a,b, 1969;1970a,b,c).

II. Vertical profiles of ionospheric parameters and ion composition

In the range of heights 80-170 km the electron density data are obtained by means of high-frequency probe on a rocket (at $h \sim 80$ km $N_e \sim 1{,}2 \cdot 10^3 cm^{-3}$) (Komrakov et al.1970).

On the basis of results of simultaneous rocket measurements of the electron density, electron temperature and ultraviolet solar radiation absorption, which was used for the estimation of the neutral composition, the heat inflow to the electron gas was determined and the existence of strong control of electron temperature at 200-300 km by the interaction of the electron gas with the neutral one was shown (Gdalevich and Shutte, 1970).

The results of ion composition measurements at $h \sim 100$-200 km show that the well-defined correlation of variations of absolute ion density with solar zenith angle variations is observed. Height and daily variations of density may be explained with the aid of photochemical theory. At height $h < 130$ km the ion-molecular reaction between O_2^+ and N must be important (Danilov,1970a).

The ion composition of the polar ionosphere was studied by means of rocket radio-frequency mass-spectrometers at height 100–180 km in the night and in the twilight. The ionosphere consisted of NO^+ and O_2^+ ions and the sharp increase of O^+ ions was observed only near 180 km. The layer of Mg^+-ions with the density equal to the density of NO^+ was discovered on one of passes at the height of 105 km (Zhludko et al.1970).

Mass-spectrometric measurements of the ion composition carried out on "Vertical space probe" showed that O^+-ions are the predominant component at middle latitudes up to the heights ~1200 km. The density of He^+-ions does not exceed the density of H^+-ions in the range of heights 600–4360 km. The ion temperature at 1000 km is 2000°K (Yershova et al.,1971).

The results of measurements on the high-altitude geophysical rockets of the Academy of Sciences of the USSR launched to the altitudes of ~500 km gave the simultaneous information about the electron density, the electron temperature and the neutral particle density (Issledovaniya verhnei atmosphery i kosmicheskogo prostranstva vypolnennye v SSSR v 1970 g. Moskva, Nauka, 1970. Soviet National Report to COSPAR,1970).

The complex study of the upper atmosphere was also carried out with the satellite Cosmos-378 (apogee ~ 1800 km, perigee ~ 240 km). Devices were installed on this satellite for measurements of all the most important parameters of the ionosphere: electron and ion density and their temperatures by means of different probe methods. In addition two identical cylindrical electrostatic analyzers with appertures oriented in opposite directions and with the energy resolution $\Delta E/E \simeq 0.3$ and the angle resolution ~ 15° were installed on this satellite for the measurement of electron fluxes with energies E ~ 0.8–10 kev. Solid-state and gas discharge counters were used for measurements of electron fluxes with E > 40 kev and ion fluxes with E ~ 1 Mev. The magnetometer was installed on the satellite for the determination of the apparatus orientation relative to the magnetic field. By the March, 4, 1970 the data for about 40 full orbits of this satellite were recorded by means of memorizing device and 260 series of measurements by means of real-time telemetry were made.

At the present these data are being processed and compared with the results of many ground-based geophysical observations carried out during the flight of the satellite. According to the preliminary data, trapped and quasitrapped electrons with $E > 40$ kev are observed to $L \cong 8$ in the night and to $L \sim 10 + 12$ in the afternoon. The gaps between the inner and outer radiation belts is observed at L = 3. At the disturbed periods in polar caps proton fluxes with $E > 1$ Kev of the intensity of 5-10 $cm^{-2}sec^{-1}$ are observed at L=15-38. Many spectra and pitch-angle distributions of electron fluxes with E=0.2 - 10 kev are recorded. Pitch-angle distributions are highly anisotropic and often have two peaks near $\theta = 0$ and $\theta = \pi/2$. Electron fluxes moving to the Earth are usually more intensive than fluxes moving in the opposite direction. Rapid variations of the spectrum and the flux by two orders of magnitude with characteristic times ≤ 1 sec are systematically observed. According to the preliminary data in the most of cases the energy spectrum peak is placed at $E < 1$ kev.

During the magnetic storm at $L \sim 3.5 - 6.9$ at the Earth's dark side intensive fluxes of electrons with $E > 0.6$ kev are observed at $21^h - 4.5^h$ UT. Sometimes the energy flux is about 100-200 $egr \cdot cm^{-2} \cdot sec^{-1}$. Near local midnight sharp boundaries of electron fluxes with $E < 10$ kev and the trough in their intensity are recorder. This behaviour pretty well correlates both with the harder radiation fluxe variations and the electron temperature Te variations in the ionosphere.

All mentioned peculiarities were also recorded with second electrostatic analyzer. The comparison of recording of both analyzers makes it possible to evaluate the flux of electrons "reflected" by the ionosphere and this flux strongly depends on the pitch-angle and the time of observations.

The recorded temperature variations are 2500-10000°K in the region of the electron precipitation.

The correlation between the electron temperature Te of the ionosphere plasma and fluxes of electrons with $E > 40$ kev is noted (Issledovaniya verhnei atmosphery i kosmicheskogo prostranstva vypolnenye v SSSR v 1970 g. Moskva, Nauka, 1970).

The method of N(h) - profiles predictions for the quiet and disturbed ionosphere is developed. The possibility of the long-term prediction of behavior of the ionosphere after the disturbance was shown and the first predictions were made (... [illegible], 1969; ..., 1970).

The method of N(h)-profiles computations is developed which takes into account between-layer and located beneath ionization with the use of two magnetoionic components of an ionogram. The possibility of the unambiguous solution of this problem is shown (Vinnikova,1970).

Problems of the application of "quasi-longitudinal" approximation in the method of partial reflections are examined. The use of the expression for the refractive index in the case of the quasi-longitudinal approximation appears to be quite correct in the study of N(h)-profiles by means of partial reflection method at $f \approx 2$ Mc in the D-region of the ionosphere at middle latitudes ($\varphi \leq 30^{\circ}$) (Grishkevich et al.1971).

III. Physics of lower ionosphere

Up to the recent time there was no quantitative coincidence of measured values of the O_2^+ - ion densities and values calculated provided that L_α and X-rays were the source of the ionization of D-region. The account of the corpuscular source at heights < 95-100 km made it possible to find the agreement of experimental data with theoretical values of intensities of ionization sources (Tulinov,1970a,b; Kochenova et al. 1971).

The influence of cosmic rays on the ionization of the lower ionosphere was also shown in the paper by Yampolsky (1970). According to this paper cosmic rays in the lower ionosphere produce the more intense ionization than the solar radiation at h < 75 during minimum and h < 65 km during maximum of the solar activity.

Fundamental problems of lower ionosphere aeronomy at h < 130 km (the night ionization of the E-region, the contents and the photochemistry of negative ions, sources of the ionization in the D-region) are examined in the review paper by Danilov (1970b).

It is worth to note the papers in which periodical wind streams in the lower ionosphere are considered. It is shown that the turbulence of the lower ionosphere causes altitude variations of periodical winds (Hantadze, 1970).

IV. The disturbed ionosphere

The investigation of ionosphere effects of proton and nonproton flares was carried out. It is shown that disturbances have a less time delay and more activity after proton flares and this is an evidence of great solar plasma-energies during proton flares (Benkova, Zevakina, 1969, 1970; Goncharova et al. 1970a,b).

The magnitude of the ionosphere parameter variations ($\Delta f_o\ F_2$, h_{max}, Y_m) at different latitudes is proportional to the flare activity and to the activity of a magnetic disturbance. Ion production rate during the positive phase of disturbances increases at all heights (from 200 km to h_{max}), and during negative phase it decreases.

On the basis of the established dependence of F-region geometric parameters on solar activity world maps of h_{max} and Y_m for different phases of solar activity are made and published. Besides the prediction of effective heights for different frequencies is regularly carried out (Anoufrieva et al. 1969).

As a result of examination of statistical distribution of the ionosphere disturbances the model of random processes well discribing the distribution of $\Delta f_o\ F_2$ at different latitudes at minimum and maximum phases of solar activity is proposed. Statistical analysis of Δf_oF_2 distributions obtained from the data of a number of ionospheric stations showed that approximately normal law of Δf_oF_2 distribution corresponds to quiet state of the ionosphere. During ionosphere disturbances the $\Delta f_o\ F_2$ – distribution considerably differs from the normal. It is shown that the use of monthly median values of f_oF_2 gives the possibility to estimate the value of the electron density variation. In this case the deflection of $W(\Delta f)$ distributions from normal ones determines the maximum possibilities of radioservices probabilities of error signals, available reliabilities which may be calculated from the data on statistics of $\Delta f_o\ F_2$ (Yudovich, Besprosvannaya, 1969; Yudovich et al. 1969; Kiyanovsky, Yudovich, 1969; Vashavatsky et al. 1970).

Studies of electron density distribution in the F_2-region and in the upper atmosphere were conducted at different phases of individual magnetic storms. It is noted that in the lower part of the F_2-region, at heights $180 \le h \le h_mF_2$, disturbance effects in $n_e(h)$ and integral electron contens as a rule coincide in the sence of the sign with variations of N_mF_2. The main effect of a magnetic storm in the night time outer ionosphere electron density at near-equatorial latitudes is the decrease of n_e (Fatkullinet al.1971b).

It is shown that the main reason for the season anomaly appearance and effects of negative disturbances during the main phase of magnetic storms in the middle-latitude dayside F_2-region and in the outer ionosphere are corresponding variations of the upper atmosphere neutral composition including levels of the turbopause. Calculations showed that at levels of the turbopause the value of $[O]/[N_2]$ or $[O]/[O_2]$ decrease by approximately 50% during the transition from winter to summer and from quiet to disturbed conditions (Fatkullin, Legenka, 1970; Fatkullin, 1971 b,c).

Studies of ionospheric disturbances at the conjugate points were continued during 1969-1970. Variations of electron density profiles were examined from the conjugate pair data (island Kerguelen-Archangelsk region) and from other pairs.

An attempt was made for explanation of synphase and antiphase disturbances of F-region as a result of electric fields which are generated at the magnetosphere boundary under the solar wind influence and penetrate into the ionosphere (Benkova et al.1968).

Variations of the lower ionosphere at conjugate points during substorms are examined (Benkova et al.1970). The data of lower ionosphere anomal ionozation are compared with balloon measurements of Bremsstrahlung caused by precipitated auroral electron fluxes. Directly measured spectra of fluxes well agree with the estimate of spectra from the polar type E_s observations.

The study of vertical ionization profiles at several pairs of observatories placed in the geomagnetically conjugated points during a disturbance showed that variations of the ionisation density in the upper part of F-region and lower part of this region are different during antiphase disturbances. The authors are inclined to the electrodynamical hypotesis for the explanation of the disturbance conjugacy in the F-region (Benkova et al. 1971).

The theory of the generation of large-scale disturbances of the electron density in the ionosphere F-region based on the interaction of ionospheric currents and electric fields with the plasma of the F-region is developed. The dependence between gravitational waves in the atmosphere and intersecting disturbances in the F-layer is cleared out (Grigoriev et al. 1970; Gershman et al. 1970).

V. Sporadic E_s-layer

The occurence of sporadic E_s-layers is known to be connected with wind shears in the ionosphere. The directions of drifts in the regular E-layer were compared with occurence of E_s. It was shown that there is a correlation between the season dependency of the occurence of c - and l - type of E_s - layer and the season variation of wind direction (i.e. of plasma drifts), but at the presence of wind with proper direction E_s occur not always, i.e. the adequate wind profile is of great importance but insufficient factor of E_s formation (Pozigoun, 1970).

The turbulent gas motions due to wind shears which are connected with the formation of thin E_s-layers induce the ionospheric currents. This currents are the cause of magnetic field variations which can be analysed (Ignatiev, 1969, 1970, 1971). E_s-peak is show to occur as a result of the travelling disturbances passage in the direction normal to the geomagnetic field. It is assumed that such disturbances are the effect of the internal gravity waves in the atmosphere (Tchernischova et al. 1970 b).

The relation of E_s occurences to the magnetic activity is investigated. In the summer at middle latitudes there is negative correlation; in the winter and in the equinoxes there is no correlation for E_s-layers with $f_o E_s \geq 5$ Mc (Zaerebtsov, Kurilov, 1970). For l - and f - type of E_s in Alma-Ata there is positive correlation (Kolesnikov et al. 1970). The effect of the absorption in the D-layer of radiowaves with different frequencies on the occurence of E_s-reflections was investigated. It was shown that appearence probability of E_s-reflections varies in the following way: before noon it increases in spite of increase of D-layer absorption due to the increase of electron density in E_s and after-noon it at first increases due to descrease of D-layer absorption and then it descreases because of E_s electron density decrease (Tchernischova et al.1970 a).

It is shown that the number of E_s-reflections mainly depends on both ionization ratio and the structure of E_s-layer and the E_s-absorption (Soltchatova et al.1970). The obtained results made it possible to conclude that in summer the night E_s-layer dissipate less of energy then the night E_s-layer in winter under all other equal conditions.

VI. Inhomogeneities and motions

The world-wide distribution of electron density fluctuations has been studied. It was calculated from the data of observations of the diffusive reflections from the ionospheric F-region. The degree of inhomogeneity was established to be essentially dependent on magnetic activity at equatorial and middle latitudes and to be almost constant in the auroral zone and the polar cap. The regular daily variations of electron density fluctuations are also observed only at low and middle latitudes. In magnetically disturbed periods the zone of large inhomogeneities essentially shifts to the equator as compared with the magnetically quiet period (Vergasova, 1968, Vergasova et al.1970 a,b).

A number of special observations of large-scale travelling disturbanes in the ionospheric F-region is carried out, the classification of this phenomenon is given, the daily and season variation of this type of ionospheric anomalies, especially so called "duplex reflections" are studied and it was found out, that the height interval most favourable for generation of disturbances is 250 ÷ 300 km; their typical velocities of horizontal movements are 40 ÷ 70 m/sec and their night values are being greater than the day values (Zaharov et al.1969; Kazimirovsky et al.1968).

The analysis of large travelling disturbances influence on the ionospheric F_2-layer parameters is carried out and it is shown that F_2-layer critical frequency rises at the substantial distance from the point disturbance onset and the peak electron density can rise at a factor of 2. The velocity of large disturbances movement is 350 m/sec, the F_2-layer critical frequency oscillates with a period of several hours after growth, the oscillation period being larger with the growth of distance from the source of disturbance (Kokourov et al.1969).

The influence of parameters of diffraction picture formed at reflection of radiowave from ionospheric disturbance on the results of determination of the velocity of horizontal drift of ionospheric inhomogeneities are studied. It was established that with the use of routine technique the curvature of difraction picture extremal lines do not exert essential errors in estimation of velocity at middle latitudes (Parhomova et al.1968).

The critical analysis of current theories of appearence and motions of inhomogeneities in ionospheric F-region in comparison with observation data are carried out. The heliocyclic variations of parameters of horizontal ionospheric drifts are studied and it was shown that during the low solar activity phase the meridional transport in the ionosphere rises.

For the first time in the field of drift study the experiments were made on synchronous measurements of horizontal drifts of small-scale ionospheric inhomogeneities at vertical and inclined reflections. The estimated horizontal drift velocity "shift" is equal 1,4 ÷ 1,6 m/sec.km (Tchernobrovkina, 1970 a,b,c,d).

In an effect of obtaining data on inhomogeneous structure of polar ionosphere from July 1966 to March 1967 at Loparskaya (Murmansk region) the observations were made of polar satellite signals with frequencies 20 and 162 Mc by interferometers of different bases. The study of morphological characteristics of satellite signal amplitude fluctuations showed that at the night time the latitude variations of fluctuation index $S = \frac{I_{max}-I_{min}}{I_{max}+I_{min}}$ for disturbed conditions essentially differ from that of quiet conditions. The maximum shifts to the south for $\sum Kp > 20$. The daily variation of S indicates that during the equinox periods the day S values are about 1,7 times more then night values. In summer the daily variations are less distinct.

The spectrum of small-scale inhomogeneities of electron density in polar ionosphere were studied from the observations of "wash-out" effect of interferometric pattern from the moving satellite. This method has the advantage of more rapid scanning of different regions of the ionosphere. The wash-out effects appeared to be caused by F-layer inhomogeneities located at heights 200 ÷ 400 km, and in some cases at h ~ 150 km (Alimov et al.1970).

Calculations of the coherent electric field value in the ionosphere in the presence of the ingomogeneity of fast electrons showed that the electron drift velocity can exceed the ion sound velocity and this in turn leads to the origin of ion-sound oscillations in the ionosphere (Zhedilina,1971).

VII. Radiowave propagation in ionosphere

In the morning sector of Arctica the existence of second zone of anomalous absorption at latitudes of auroral oval was observed (Gorboushina, Julina,1970).

The measurements of regular radiowave absorption in ionospheric auroral zone by radioastronomical method showed that duirnal and season variations of integral absorption are controlled by solar radiation in the same degree as at temperate latitudes (Benediktov et al.1970).

The estimates were made of influence of horizontal ionization gradients on MUF values, hop distance and angles of radiation (Kerblai et al.1970; Kovalevskaya, Kornitskaya,1969); the discrepancies in these values in the calculations with the use of curves of transmission and calculations of refraction integral were also estimated (Kerblai, Kovalevskaya,1971). It was shown to which variations in propagation conditions leads the presence of horizontal gradients of electron density; the conclusion was made that the most effective are the f_oF_2 gradients whereas the gradients of geometric parameters of the layer can be essential only under some conditions and in most cases they can be neglected (Kerblay, Ishkova,1971).

The possibilities of arrival of a number of rays to the same distance were estimated for the cases of linear and parabolic approximation of electron density distribution in a layer and it was concluded that in the case of linear height distribution only one ray can arrive to the given distance at fixed frequency.

The method of number solution of short wave difraction problems in inhomogeneous mediums on the base of the solution of the parabolic equation of diffraction theory in ray coordinates. The coordinate lines in ray coordinates are the families of fronts and rays. The differential operators are given which describe the wave amplitude diffusion along the wave front with the successive transition from the previous to the subsequent front along the propagation direction (Tscherkashin,1971).

Measurements of the radiowave absorption carried out during the oblique propagation through the ionosphere revealed the possibility of the recalculation of the absorption value measured during a vertical radiowave propagation to the absorption value for the oblique propagation on the ground of the ray geometry (Belikovitch et al.1971).

VIII. Electric field in Earth's ionosphere and magnetosphere and its influence on ionospheric dynamics

The problem of generation of static and quasistatic electric field in the Earth's ionosphere and magnetosphere was considered from the theoretical point of view. The method of kinetic equation showed that fast electron and ion movement is accompanied by the appearance of strong potential electric field. The obtained equations describe this electric field and its influence on fast particles and ionosphere. The dimensionless parameter λ was found out, which is proportional to the density of fast particles and which determine the influence of the electric field on inhomogeneity movement. It was shown that inhomogeneity of fast particles at $\lambda \to 0$ spreads out and transforms to a radiation belt in a time of ~ 2-3 periods of their revolution around the Earth (Gourevitch et al.1969-1971). The equations are obtained and analysed for the electric field which appears at the spreading of man-made fast particle inhomogeneities in the Earth's magnetosphere (Tscedilina, 1970; Soboleva, Tscedilina, 1971) and also as a result of the interaction between geomagnetically trapped protons of solar wind and thermal ionospheric plasma. The electric field was shown to be of world-wide nature. Immediately after appearence of fast electron and ion inhomogeneity the complicated picture of electric field distribution occur in the Earth magnetosphere and ionosphere. The field structure is close to quadrupole picture and the electric field value quickly decrease.

IX. Other points

The comparison of ionospheric characteristics of Earth group planets - Venus, Earth and Mars - are made. The forms of height profiles of concentration are similar in the ionospheres of all three planets. For example, there is second peak of ionization located beneath the principal maximum, the concentration values in the principal maximum are the same order; there is plasmapause - sharp outer boundary in the Earth and Venus ionospheres et al. However, the mechanisms of ionosphere formation at various planets are different due to lack of inherent magnetic field on Mars and Venus and outwardly similar phenomena can be of different nature (Gringauz, Breus, 1969, 1970).

References

Alimov V.A., Getmantsev G.G., Yerukhimov L.M., Mityakov N.A., Rapoport V.O., Uryadov V.P., Cherepovitski V.A. (1970) Geom. and Aeron. 10, No 1, 28

Anufriev T.A., Shapiro B.S. (1969) "Ionospheric Research", No 17, "Nauka", 59

Belicovitch V.V., Benedictov Ye.A. (1971) Geom.and Aeron., 11, No 3, 547

Benediktov Ye.A., Dubkova V.A., Tolmacheva A.V. (1970) Geom. and Aeron. 10, No 4, 620

Besprozvannaya A.S. (1970 a) Geom.and Aeron., 10, No 6, 994

Besprozvannaya A.S. (1970 b) Geom.and Aeron., 10, No 1, 56

Benkova N.P., Bukin G.V., Davust K., Kerblai T.S., Taieb Sh. (1968) Geom.and Aeron., No 3

Benkova N.P., Zevakina R.A. (1969) Annals of the IQSY, 3, 448

Benkova N.P., Zevakina R.A. (1970) "Ionospheric Research", No 19, "Nauka", 41

Benkova N.P., Bukin G.V., Kalisher A.D., Troitskaya V.A. (1970) Geom.and Aeron., No 5

Benkova N.P., Bukin G.V., Chin Hong Tien (1971) Geom.and Aeron., 11, No 4, 602

Boenkova N.M. (1970) Geom.and Aeron., 10, No 3, 541

Vergasova G.V. (1968) Geom.,aeron.and solar physics research", v.3, 92

Vergasova G.V., Kokourov V.D. (1970) Ionospheric Research,140

Vergasova G.V., Sidorova S.G., Chernobrovkina N.A. (1970 a) Geom.,aeron.and solar physics research", v.13, 81

Vergasova G.V., Chernobrovkina N.A. (1970 b) Geom.,aeron.and solar physics research", v.15, 133

Vinnikova G.L. (1970) Geom.and Aeron., 10, No 2, 346

Velichanski B.N., Ivelskaya M.K., Klimov N.N. (1970) Geom., aeron.and solar physics research, v.10, SIBIZMIR

Velichanski B.N., Klimov N.N., Krinberg I.A. (1971) Geom.and Aeron., 11, No 2, 451

Vsechsvatskaya I.S., Sergeenko N.P., Yudovich L.A. (1970) Geom.and Aeron., 10, No 4, 606

Gdalevich G.L., Shutte N.M. (1971) Space Res.XI

Goncharova Ye.Ye., Zevakina R.A., Lavrova Ye.V., Yudovich L.A. (1970 a) Geom.and Aeron., 10, No 1, 67

Goncharova Ye.Ye., Zevakina R.A., Lavrova Ye.V., Yudovich L.A. (1970 b) Geom.and Aeron., 10, No 3, 547
Gorbushina G.N., Julina Ye.. (1970) Geom.and Aeron., 10, No 5, 913
Gershman .N., Samsonov A.V. (1970) ...., 1, 73
Gringauz K.I., Breus T.K. (1969) Space Research, 7, v.6; (1970) Sp.Sci.Rev., 10, 745
Grigoriev G.I., Dokuchaev V.P. (1970) Physics of Atm.and ocean, 6, No 7, 678
Grishkevich L.V., Ivanov V.A., Fedoseeva ... (1971) Geom. and Aeron., 10, No 2, 348
Gurevich A.V., Tsedilina Ye.Ye., Scherbakov ... (1970) Uspekhi fizicheskich nauk, 104, No 6, 329
Gurevich A.V., Tsedilina Ye.Ye., (1969) Geom.and Aeron., 9, 453, 642, 818
Gurevich A.V., Scherbakov V.P. (1970) Kratkie soobscheniya po fizike, No 6, 52
Danilov A.D. (1970 a) Geom.and Aeron., 10, No 5, 1
Danilov A.D. (1971) Space Res., XI
Ershova V.A., Sivsova L.D., Yarin V.I. (1971) Geom.and Aeron., 11, No 5, 741
Zsherebtsov G.A., Kurilov V.A. (1970) Geom.and Aeron., 10, No 1
Zahludko A.D., Tulinov V.F., Klueva N.., Chasovitin Yu.K. (1970) Geom.and Aeron., 10, No 4, 741
Zakharov V.N., Kazimirovski A.S., Kokourov V.D. (1969) Geom. and Aeron., 9, No 5, 935
Ivanov-Kholodni G... (1970) Geom.and Aeron., 10, No 3, 385
Ignatiev Yu.L. (1969) Geom.and Acron., 9, No 6
Ignatiev Yu.L. (1970) Geom.and Aeron., 10, No 5, 909
Ignatiev Yu.L., Krotova Z.N. (1971) Geom.and Aeron., 11, No 5
Issledovaniya verhnei atmosphery i kosmicheskogo prostranstva vypolnennye v SSSR v 1970 g. Moskva, Nauka, 1970 (Soviet National Report to COSPAR, 1970)
Kazimirovski A.S., Kokourov V.D. (1968) Geom.,aeron.and solar physics research, v.3, 1, 46
Kerblai ..., Kovalevskaya Ye... (1971) Geom.and Aeron., 11, No 2

[illegible] ([illegible]1) Geom.and Aeron., 11, No 2
Kovalevskaya Ye.[illegible], [illegible] Ye.A. (1969) Geom.and Aeron., 9, 290
Kiyanovski [illegible], Yudovich L.[illegible] (1969) Ionospheric Research, "Nauka", No 17, 33
Klimov [illegible], Schepkin L.A. (1970) Geom.and Aeron., 10, 534
Klimov N.N., Polyakov V.[illegible], Kuznetsova G.[illegible], Gershengorn G.I. (1969) Geom.and Aeron., 9, 655
Klimov N.N., Soloviev Yu.P. (1968) Geom.and Aeron., 8, 177
Kokourov V.D., Chernobrovkina N.A. (1969) Ionospheric Research No 17, 209
Komrakov G.P., Ivanov V.P., Popkov I.V., Tukin V.A. (1970) Space Research VIII, 2, 278
Kolesnikov T.V., Starovatov A.A., Filonova L.D. (1970) Geom. and Aeron., 10, No 2, 358
Kochenova N.A., Fligel M.D. (1971) Geom.and Aeron., 11, No 3, 478
Koshelev V.V., Schepkin L.A., Shuiskaya Z.I. (1970 a) Geom., aeron. and solar physics research, v.22, 80-93, "Nauka"
Koshelev V.V., Shuiskaya Z.I., Schepkin L.A. (1970 b) Geom. and Aeron., 10, No 4, 727-729
Koshelev V.V., Schepkin L.A. (1970) Geom.and Aeron., 10, No 2, 342-344
Koshelev V.V., Schepkin L.A., Potomkov V.I. (1970) Geom.and Aeron., 10 No 5, 903-905
Krasnushkin P.Ye., Knyazeva T.A. (1970) Geom.and Aeron., 10, No 6, 993
Nikanorova R.Sh., Schukina T.B. (1970) Ionospheric research, "Nauka", Novosibirsk,114-123
Parkhomova L.D., Chernobrovkina N.A. (1968) Geom.,aeron.and solar physics research, v.3, 70
Pozigun V.L. (1970) Geom.and Aeron., 10, No 5, 907
Solchatova L.Ya., Zsharnikova T.V., Pezshemskaya M.D. (1970) Geom. and Aeron., 10, No 6, 1090
Tulinov V.F. (1970 a) Geom.and Aeron., 10, No 3, 538
Tulinov V.F. (1970 b) Geom.and Aeron., 10, 41, 737
Fatkullin M.N., Legenka A.D. (1970) Geom.and Aeron., 10, No 3, 435
Fatkullin M.N. (1971 a,c) Geom.and Aeron., 11, No 3, 534

Fatkullin M.N., Legenka A.D. (1971 a) Geom.and Aeron., 11, No 1
Fatkullin M.N., Legenka A.D., Romanenko A.V. (1971 b) Geom. and Aeron., 11, No 5, 901
Fatkullin M.N. (1971 d) Geom.and Aeron., 11, No 4, 711
Khantadze A.G. (1970) Geom.and Aeron., 10 No 2, 351
Chernisheva S.P., Riss I.K. (1970 a) Geom.and Aeron., 10 No 2, 356
Chernishova S.P., Sheftel V.M., Mozshaev A.M. (1970 b), 10, No 6, 1087
Cherkashin Yu.I. (1971) Radiotechn.and Electronic, 16, No 1
Chernobrovkina N.A. (1970 a) Ionospheric Research, 178
Chernobrovkina N.A. (1970 b) Geom.aeron.and solar physics research, v.13, 77
Chernobrovkina N.A. (1970 c) Geom.,aeron.and solar physics research, v.13, 73
Chernobrovkina N.A. (1970 d) Geom.,aeron.and solar physics research, v.13, 68
Tsedilina Ye.Ye. (1970) Geom.and Aeron., 10, 408
Tsedilina Ye.Ye. (1971) Geom.and Aeron., 11,464
Shapiro B.S. (1970) Geom.and Aeron., 10, No 2, 344
Shashunkina V.M. (1969), Geom.and Aeron., 9, No 2, 259
Schepkin L.A. (1968 a) Geom.,aeron and solar physics research (Ionospheric research), No 3, 2, 12-30
Schepkin L.A. (1968) Geom.and Aeron., 8, No 4, 785-786
Schepkin L.A. (1969) Geom.abd Aeron., 9, No 1, 161-162
Schepkin L.A. (1970 a) Geom.,aeron.and solar physics research, No 12, M., "Nauka", 48-61
Schepkin L.A. (1970 b) Geom.,aeron.and solar physics research, No 12, M., "Nauka", 63-69
Schepkin L.A. (1970 c) Geom.,aeron. and solar physics research, No 12, (SIBIZMIR), M, "Nauka", 104-110
Schukina T.B. (1970) Ionospheric research, Novosibirsk, "Nauka", 124-130
Yudovich L.A., Besprozvannaya A.S. (1969) Geom.and Aeron., 9, No 5, 856
Yudovich L.A., Goncharova Ye.Ye., Nosova G.N. (1969) Ionospheric research, No 17, "Nauka", 77
Yampolski V.S. (1970) Geom.and Aeron., 10, 2, 360